

*DISCRIMINATION AND DIFFERENTIATION OF  
RESPONSE NUMBER IN STIMULUS  
DIRECTED PECKING OF PIGEONS*

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In Experiment 1, autoshaping trials terminated with food only if pigeons emitted more than a target number of responses during a trial in one condition and fewer than a target number in another. The median number of responses per trial shifted in accordance with the requirements. The responding of yoked-control birds that received response-independent reinforcers did not vary with the response requirements. In Experiment 2, the number of responses in an autoshaping trial became the discriminative stimulus for reinforcement in the second component of a chained schedule. In one condition, responding was reinforced only if the number of responses in the first component was above a target value; in the other condition, responding was reinforced only if the number was below the target value. The distribution of the first-component response numbers did not shift systematically between discrimination conditions, but response rates in the second component indicated that the number of responses in the autoshaping trial was a discriminable property of behavior.

*Key words:* response discrimination, response differentiation, autoshaping, key peck, pigeons

In autoshaping (Brown & Jenkins, 1968), a brief illumination of a response key reliably precedes food presentation. In omission training (Williams & Williams, 1969), but not in autoshaping, any response while the key is illuminated cancels the food presentation and may terminate the trial immediately. Like autoshaping, omission training elicits key pecks in naive pigeons over a fairly wide range of schedule parameters, and key pecks persist over many sessions of both autoshaping and omission training. The omission contingency does not lack influence, however; key pecking on schedules of omission training occurs on fewer trials (Williams & Williams, 1969), at a lower rate (Schwartz & Williams, 1972a), with greater variability in location (Barrera, 1974), and possibly with shorter duration (Schwartz & Williams, 1972b) than on autoshaping schedules.

Another strategy used to assess the influence of the response-reinforcer relation in autoshaping trials has been to have food depend on the occurrence or nonoccurrence of re-

sponses in one or both halves of a trial. Deich and Wasserman (1977) and Wasserman (1977) presented food when responses were confined to various segments of an 8-sec trial. Different within-trial patterns of responding were established by the various response-reinforcer relations. Apparently, a response-reinforcer relation may have considerable influence over stimulus-directed responding.

Research that explores a range of response requirements may help to broaden the experimental basis of statements concerning stimulus- and response-reinforcer relations in autoshaping and omission training. In the first experiment reported here, the stimulus continued to predict reliably the occurrence of the reinforcer, thus varying the stimulus-reinforcer relation very little. Concurrently, the response-reinforcer relation was varied over a greater range than has previously been examined within the autoshaping and omission training paradigms.

For subjects to adhere closely to the requirements of a response-reinforcer relationship, they may need to discriminate and remember some aspect of their responding. Rilling (1967) and Buchman and Zeiler (1975) have shown that the number of responses in fixed-interval schedules can serve as discriminative stimuli, and Pliskoff and Goldiamond (1966) and Hobson (1975) have shown that the number of

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responses in fixed-ratio schedules is discriminable. In the second experiment, we explored the discriminability of responses occurring in autoshaping trials.

## EXPERIMENT 1

### DIFFERENTIAL REINFORCEMENT OF RESPONSE NUMBER

#### METHOD

##### *Subjects*

Eight experimentally naive Silver King pigeons ranging in age from 6 to 9 years served. They were housed individually with free access to grit and water and were maintained at about 80% of their free-feeding weights.

##### *Apparatus*

The six experimental chambers had Plexiglas walls and were 35 cm high, 35 cm wide, and 35 cm deep. The front panel of each chamber contained a single response key mounted behind a 2.5-cm diameter circular aperture, centered on the panel 25 cm above the grid floor. The 5-cm<sup>2</sup> feeder aperture was 10 cm above the floor, directly below the response key. White light could transilluminate the key, and white light illuminated the grain during the feeder cycle. A 6-W white houselight (GE 1819) mounted centrally at the top of the chamber provided diffuse illumination. The chambers were contained in ventilated, sound-attenuating wooden shells located in several small rooms separated from the control room. White noise masked most extraneous sounds. Experimental contingencies were programmed with the SKED software system.

##### *Procedure*

In the first few sessions, the birds were trained to eat readily from the food hopper by intermittent 4-sec grain presentations. In the next sessions, the response key was illuminated for 8 sec with white light, and then food was presented for 4 sec. The keylight remained dark during the variable intertrial interval (mean = 90 sec). Five sessions of 40 trials each were conducted weekly. Next, the eight birds were paired on the basis of their initial autoshaped behavior so that each member of a pair had roughly the same rate of

autoshaped key pecking. For the remainder of the experiment, the presentation of food at the end of a trial was determined for both birds only by the responding of the master bird. For the master bird, food was omitted whenever a trial contained fewer than a required number of responses. The response requirement is abbreviated  $R \geq X$ , where  $X$  is the required number of responses. After autoshaping ( $R \geq 0$ ), the value of  $X$  was increased from zero to a value that corresponded to the 25th percentile of the master bird's number of responses per trial, thus differentially reinforcing trials containing large numbers of responses (a discrete trials differential reinforcement of high rate, or DRH, schedule). The value of  $X$  was incremented by two after a bird had obtained food on at least two-thirds of the trials over a 3-day period, or after 10 days, whichever came first. If a bird failed to obtain food on at least one-third of the trials in a session, the DRH stage ended. The next stage (DRL stage), abbreviated  $R \leq X$ , involved differential reinforcement of trials containing a small number of responses and a low rate. The value of  $X$  at first corresponded to the 75th percentile of the master bird's number of responses per trial in the preceding sessions and was reduced according to the same rule used in the DRH stage. The penultimate condition ( $R = 0$ ) was negative automaintenance in which any response during the trial cancelled the food presentation. Finally, autoshaping trials ( $R \geq 0$ ) were presented once again. Throughout the experiment only the number of responses in a trial determined the outcome of the trial; food was not necessarily contiguous with responding, and responding during the intertrial interval had no consequence. Table 1 shows the sequence of response requirements and the number of sessions per requirement for each pair of birds.

Exceptions to the rule governing shifts in the response requirements occurred when a master bird's behavior was no longer contacting the contingency; as, for example, if the requirement was  $R \geq 2$ , but the bird always emitted 10 or more responses per trial. In such cases, the value of  $X$  was changed to correspond to the 25th or 75th percentile of the master bird's number of responses per trial in the DRH and DRL stages, respectively. A second exception to the rule occurred with the

Table 1

Sequence of response requirements with number of sessions in parentheses.

Birds (master-yoke)	Response requirement and number of sessions
5038-7116	$R \geq 0(5)$ , $R \geq 1(6)$ , $R \geq 16(2)$ , $R \geq 18(3)$ , $R \geq 20(7)$ , $R \geq 0(3)$ , $R \leq 20(6)$ , $R \leq 18(5)$ , $R \leq 16(3)$ , $R \leq 14(10)$ , $R \leq 12(3)$ , $R \leq 10(8)$ , $R \leq 8(5)$ , $R \leq 6(3)$ , $R \leq 4(3)$ , $R \leq 2(10)$ , $R \leq 0(13)$ , $R \geq 0(13)$
7136-9216	$R \geq 0(5)$ , $R \geq 1(8)$ , $R \geq 2(3)$ , $R \geq 3(6)$ , $R \geq 4(6)$ , $R \geq 5(5)$ , $R \geq 8(25^*.3)$ , $R \geq 9(1)$ , $R \geq 10(5)$ , $R \geq 11(2)$ , $R \geq 12(3)$ , $R \geq 13(3)$ , $R \geq 14(3)$ , $R \geq 15(10)$ , $R \geq 16(5)$ , $R \geq 17(3)$ , $R \geq 18(3)$ , $R \geq 20(3)$ , $R \geq 22(3)$ , $R \geq 24(7)$ , $R \geq 0(4)$ , $R \leq 4(4)$ , $R \leq 2(3)$ , $R \leq 0(4)$ , $R \leq 0(4)$
6403-7695	$R \geq 0(4)$ , $R \geq 18(4)$ , $R \geq 20(8)$ , $R \geq 22(5)$ , $R \geq 0(4)$ , $R \leq 20(10)$ , $R \leq 18(5)$ , $R \leq 16(7)$ , $R \leq 14(3)$ , $R \leq 12(4)$ , $R \leq 6(8)$ , $R \leq 4(13)$ , $R \leq 2(10)$ , $R \leq 0(6)$ , $R \leq 0(1)$
6901-6502	$R \geq 0(4)$ , $R \geq 8(4)$ , $R \geq 10(3)$ , $R \geq 12(3)$ , $R \geq 16(4)$ , $R \geq 18(8)$ , $R \geq 20(10)$ , $R \geq 22(3)$ , $R \geq 0(5)$ , $R \leq 18(3)$ , $R \leq 16(3)$ , $R \leq 14(3)$ , $R \leq 2(4)$ , $R \leq 0(9)$ , $R \leq 0(3)$

\*Adjusting schedule; see text for explanation.

pair of Birds 7136 and 9216. The requirement  $R \geq 4$  had little effect on responding at first; consequently, an adjusting schedule modified the value of  $X$  on a trial-by-trial basis. After two consecutive reinforced trials,  $X$  was increased by one; and after four consecutive unreinforced trials,  $X$  was decreased by one. This schedule served to increase the number of responses per trial and was discontinued after 25 sessions, when the requirement reached  $R \geq 8$ . These sessions are marked with an asterisk in Table 1.

## RESULTS

The primary dependent measure was the number of responses during the 8-sec trials. The data presented were summarized over the final three sessions with a particular response requirement or over all sessions when requirements were in effect for fewer than three sessions.

Figures 1 and 2 show the median number of responses per trial for the four pairs of birds. The results fall into two categories. The master birds shown in Figure 1 made many responses per trial during the initial autoshaping sessions. The DRH response requirements did

not appreciably increase the median number of responses per trial; however, in the DRL stage, both master birds reduced their median number of responses per trial systematically with the requirement. At  $R = 0$ , the two master birds responded on 23% and 73% of the trials, respectively. After the second stage, which had reduced the median number of responses considerably, exposure to autoshaping trials did not reestablish the level of responding observed at the start of the DRH stage. In contrast, the master birds shown in Figure 2 made rather few responses during the initial autoshaping sessions, and the DRH response requirements increased the median number of responses systematically. In the DRL stage, the median number of responses decreased considerably, so that only the requirements  $R \leq 4$ ,  $R \leq 2$ , and  $R = 0$  had any direct contact with the birds' behavior. At  $R = 0$ , the two master birds responded on 15% and 32% of the trials, and when autoshaping trials were reinstated, responding did not recover even to the low rates observed during the first presentation of autoshaping trials.

The yoked control birds responded on virtually all trials, with individual fluctuations in the median number of responses observed during the second stage. The medians for Bird 7695 were considerably more variable than those of Bird 7116. Bird 6052 increased its median abruptly during the DRH phase, and Bird 9216 briefly increased its median initially, then decreased its median over the remainder of the experiment.

For the master birds, the distribution of response latencies was sharply peaked at 1 and 2 sec during the DRH stage, but during the DRL stage the latencies increased somewhat and the distribution tended to be uniform over the 8-sec trial. Except for Bird 9216, the four yoked birds had a constant modal latency of 1 to 3 sec. The response latency for Bird 9216 increased in both duration and variability during the last half of the DRH stage and throughout the DRL stage.

Figure 3 shows the average rate of responding during the 8-sec trial at several different response requirements for all of the birds. Each curve represents an average based on 120 trials at the particular requirement. In general, the rate of responding was very low during the first second, accelerated during the

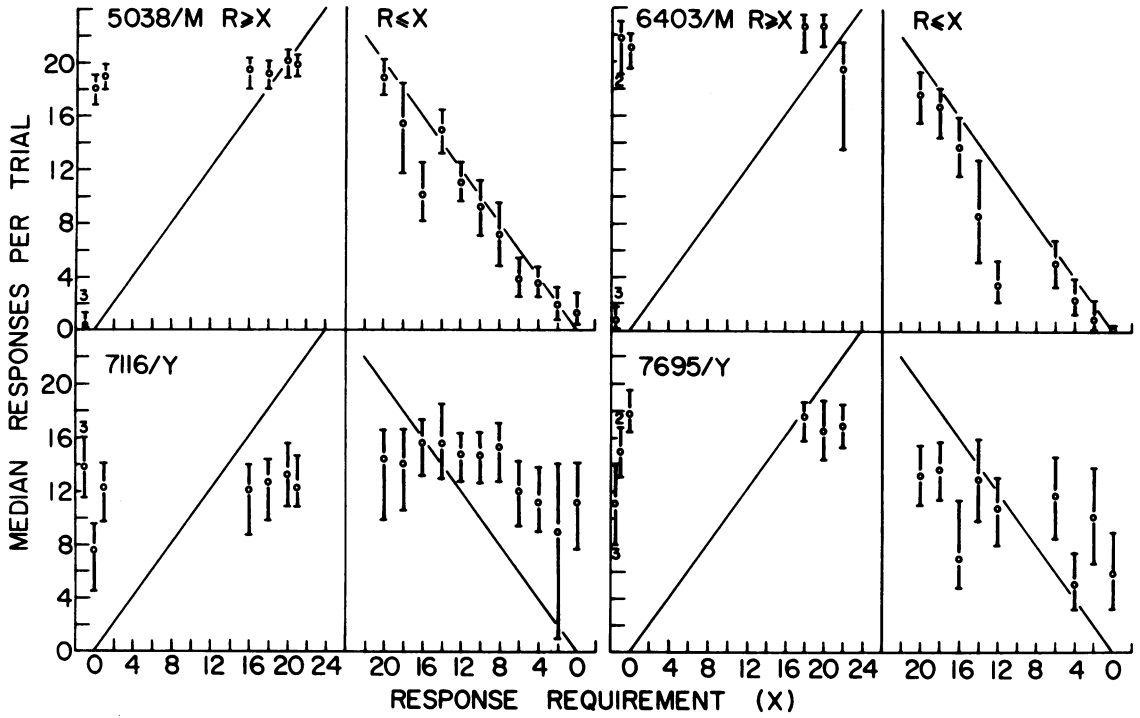


Fig. 1. The median number of responses per 8-sec trial as a function of the response requirements shown along the abscissa. The lines extending above and below each point show interquartile ranges. Trials with response numbers above the rising diagonal or below the falling diagonal terminated with food. The vertical line separates the first and second stages of the experiment. The points marked "2" and "3" are from the sessions that separated the first and second stages, and the final sessions, respectively. The left panels show data for the pair 5038 and 7116, and the right panels for 6403 and 7695.

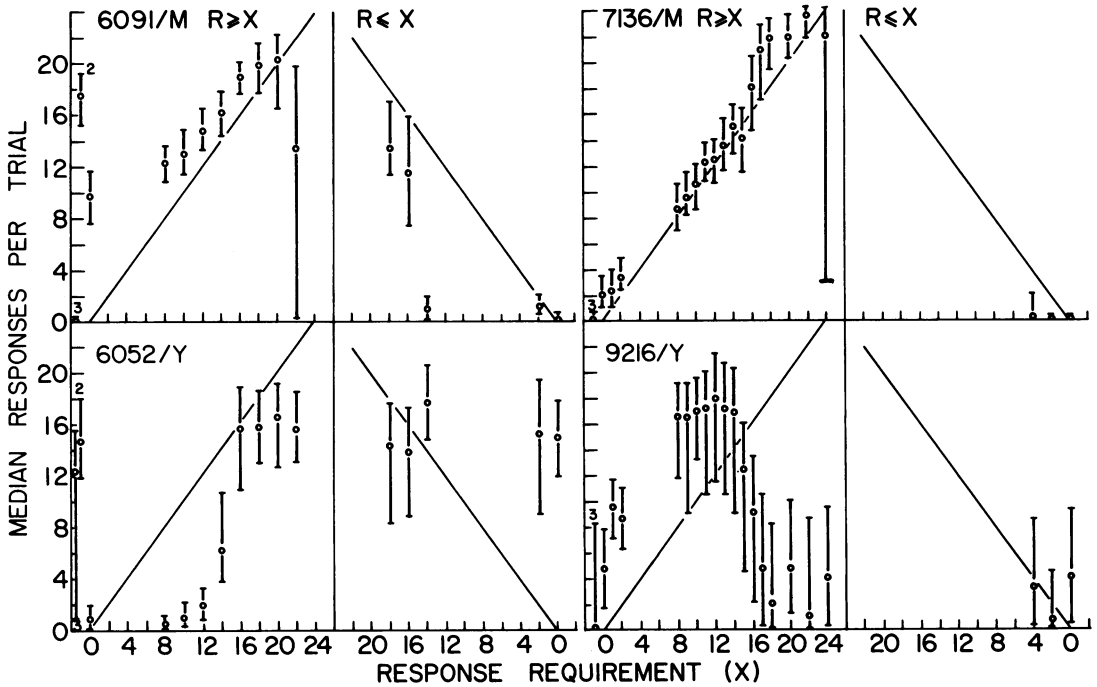


Fig. 2. The left panels show data for the pair 6091 and 6052, the right panels for 7136 and 9216. The legend is the same as for Figure 1.

next few seconds, and then remained at an asymptotic rate. For the master birds, increased numbers of responses per trial were accomplished by greater rates of acceleration and higher asymptotic rates of responding. Similarly, the decreased numbers of responses in the DRL stage were characterized by lower asymptotic rates and either reduced rates of acceleration or by an increased latency to respond. The patterns of responding in the second stage were more homogeneous than in the first stage.

There was only a slight difference between the patterns of the master and yoked birds. In the second stage, the patterns were fairly stable across the yoked birds, resembling the patterns observed at the end of the first stage. The second-stage patterns differed from those observed in the master birds in that the response-rate functions tended to be sigmoidal and lacked the rapid acceleration in the first half of the trial.

### DISCUSSION

For the master, but not the yoked-control, birds, the number of responses per trial varied systematically with a wide range of DRH and DRL response requirements. Factors other than the imposed response-reinforcer relation may have influenced all birds, nonetheless.

In the present study, between 66% and 100% of the trials terminated with food after the initial training. Gonzalez (1974) terminated 10-sec illuminations of a response key with food on 100%, 50%, 25%, 12.5%, and 0% of the trials. The mean response rate during the trials was greatest when 50% of the trials terminated with food. Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger, and Ricci (1975) presented five key colors that predicted food on 100%, 33%, 11%, or 4% of the trials. The highest rates of responding occurred to the colors that predicted the 33% and 100% reinforcement schedules. Consequently, it is

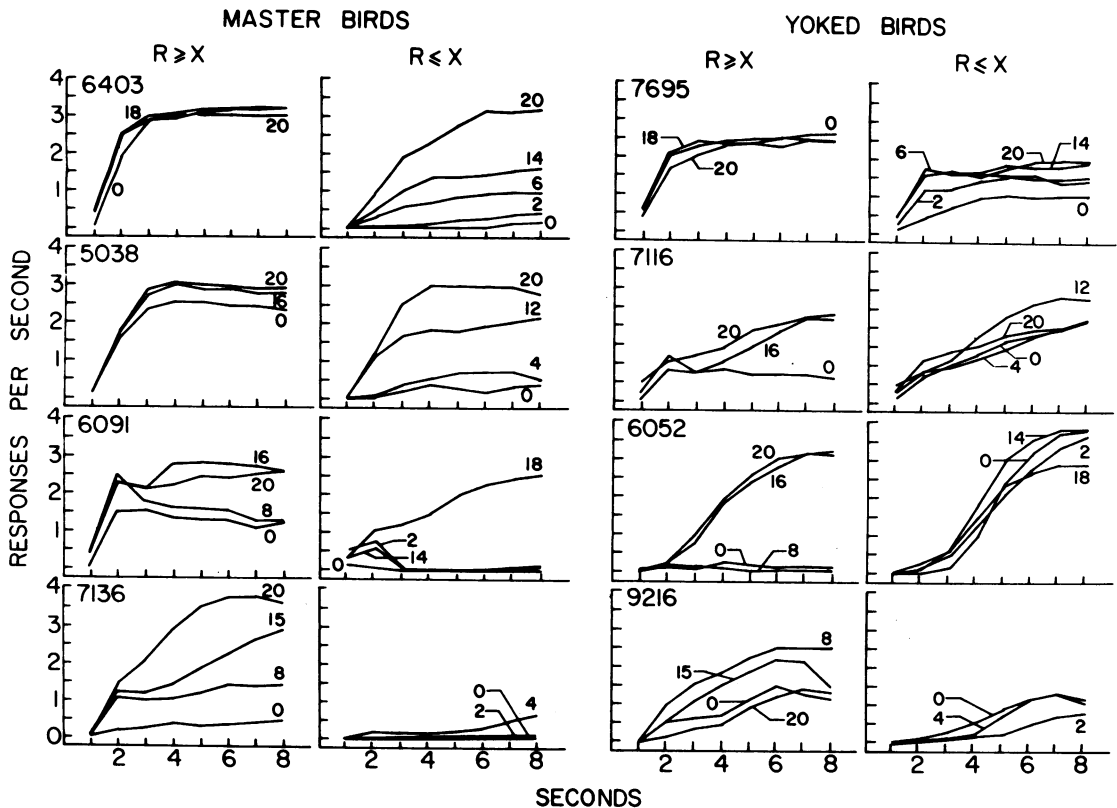


Fig. 3. The rate of responding at each second during the 8-sec trial. The numbers beside each curve show the particular response requirement. The two left columns show the master birds in the two stages, and the right two columns show the yoked birds.

not surprising that several yoked-control birds increased their response rates somewhat. The increase in the rates of the master birds may have been due to a moderate decrease in the percentage of trials ending with food. However, that influence cannot account for the marked change in the number of responses per trial that was correlated with the response requirements, nor can it account for the systematic reduction in the number of responses per trial in the DRL stage.

The influence of extended exposure to a response-independent reinforcement schedule is difficult to assess formally within the context of the present experiment. An inescapable observation from studies of autoshaping, however, is that over many sessions of training, with and without experimental manipulations, rates of responding are inherently unstable and tend to shift upward and downward with time. This variability was apparent in data reported by Schwartz and Williams (1972a). Red-key trials signaled an omission schedule, and white-key trials terminated with response-independent food at the same frequency as food had occurred after red-key trials. Over the first 36 sessions, the percentage of white-key trials with at least one response and the rate of responding during trials fluctuated considerably. The same variability was observed in several of the studies reported by Perkins et al. (1975). These observations suggest that the fluctuations in response rates seen in the yoked birds were simply due to extended exposure to a response-independent schedule. The absence of the same fluctuations in the master birds supports the view that their responding was controlled by influences beyond the stimulus-reinforcer relation, in particular by the imposed response-reinforcer relation.

## EXPERIMENT 2

### DISCRIMINATION OF RESPONSE NUMBER

The discrimination procedures of Buchman and Zeiler (1975) and Weisman and Dodd (1979) were modified to investigate the discriminative properties of the number of responses in an autoshaping trial. Following a variable intertrial interval, a two-component, discrete-trials chained schedule involved an autoshaping trial in the first component. The

number of responses emitted in the first component determined whether the second component would terminate with reinforcement. If response rate in the second component varied systematically as the number of responses emitted shifted above and below the criterion, this would indicate the extent to which the number of responses served as discriminable stimuli.

## METHOD

### *Subjects*

Six male Silver King and six male White Carneaux pigeons, aged 5 to 7 years, served. One bird (6168) had brief experience with the response-reinforcer relationships studied in Experiment 1. The birds were maintained at about 80% of their free-feeding weights, with free access to grit and water.

### *Apparatus*

The chambers were those of Experiment 1. The only modification was that the response key could be transilluminated with either white or green light.

### *Procedure*

All birds were magazine trained in two or three sessions containing 40 5-sec food presentations separated by an average intertrial interval of 90 sec. Next, autoshaping trials consisting of 8-sec keylight presentations followed by 4-sec food presentations established key pecking to a white keylight. Several sessions of fixed-ratio and variable-interval reinforcement ensured that the birds responded reliably to presentations of the white keylight. The schedule through the remainder of the experiment was a discrete-trial two-component chained schedule. After a variable intertrial interval averaging 90 sec, the first component was an 8-sec illumination of a green keylight followed by a 2-sec presentation of food. In the second component, a white keylight either terminated with a response-dependent reinforcer or terminated without food. The key was dark during the intertrial interval and during food presentations.

*Replication 1.* During initial baseline sessions, three of every four trials terminated with response-produced food after a variable interval of 15 sec had elapsed. The intervals ranged from 1 to 29 sec in an arithmetic series. On one trial of every four, randomly dis-

tributed, the second component terminated without food after 15 sec. There were 40 trials daily, 5 days a week. After 8 to 16 baseline sessions, as shown in Table 2, the number of responses in the first component became the discriminative stimulus for the schedule in the second component. The two experimental conditions will be abbreviated as in Experiment 1. In this experiment, however,  $R \geq X$  indicates that when the number of responses in the first component was greater than or equal to the target number, the second component would terminate with response-produced food on three of four trials, and without food on one of four trials as in the baseline sessions. When the number of responses in the first component was below the target number, the second component always terminated without food after 15 sec. In the other condition,  $R \leq X$ , the second component terminated with food only when the number of responses in the first component was smaller than or equal to the target number.

Three birds were randomly assigned to the  $R \leq X$  condition and three to the  $R \geq X$  condition. For each bird, the value of  $X$  was set at an integer value just above or below the median number of responses in the first component over the last five sessions (200 trials) of baseline training. If the median number of responses in the first component shifted so that a bird was exposed to a preponderance of reinforced or unreinforced trials, the value of  $X$  was shifted to achieve a more even balance. Baseline sessions were reinstated when the median number of responses in the first component had been stable for 5 days and the function relating first- and second-component responding seemed to have changed from that observed during the baseline sessions, or after a maximum of 25 sessions at a particular value of  $X$ . Next, each bird entered the other experimental condition, with the value of  $X$  determined from the baseline sessions and adjusted as described above. The number of sessions in the two baseline and two experimental sessions is shown in Table 2.

**Replication 2.** To examine the generality of stimulus control, six more birds were studied in a second replication. Lengthy baseline training was omitted, and the basic schedule was modified in four ways: (a) the arithmetic series of intervals in the second component was replaced with one from the exponential

Table 2

Slopes of the linear functions relating first- and second-component responding for each baseline and discrimination condition. The number of sessions in each condition, and for the discrimination conditions the final target value of  $X$ , are shown in parentheses. The two right columns show the  $t$ -scores and degrees of freedom for the difference between the slopes in the two discrimination conditions.

Bird	BL1	DISC1	BL2	DISC2	t	df
7210	3.87 (10)	8.04 (22, $R \geq 2$ )	1.26 (6)	-4.76 (29, $R \leq 0$ )	2.52*	236
5679	3.87 (8)	4.66 (8, $R \geq 19$ )	2.72 (11)	1.70 (22, $R \leq 12$ )	3.20**	355
6316	1.30 (9)	3.90 (19, $R \geq 17$ )	3.32 (9)	.61 (36, $R \leq 19$ )	7.23**	313
6168	1.80 (11)	-.22 (38, $R \leq 6$ )	1.09 (20)	2.19 (17, $R \geq 5$ )	2.29*	306
7758	2.20 (16)	1.53 (20, $R \leq 3$ )	2.29 (10)	3.60 (20, $R \geq 4$ )	2.55*	333
7778	.90 (13)	-.48 (20, $R \leq 13$ )	.04 (10)	.68 (25, $R \geq 12$ )	2.18*	293

\* $p < .05$ .

\*\* $p < .01$ .

series described by Fleshler and Hoffman (1962); (b) the duration of reinforcement in the second component was reduced from 4 sec to 3 sec; (c) the proportion of trials in which the second component terminated with reinforcement after an appropriate number of first component responses was increased from three of four to five of six; and (d) the number of trials per session was increased from 40 to 48.

Following four baseline sessions in which half of the trials ended with reinforcement, the birds were exposed to both discrimination conditions; three birds were randomly assigned to the  $R \geq X$  condition first, and three to the  $R \leq X$  condition first. Each day, the median number of responses in the first component was compared with the value of  $X$ , and  $X$  was adjusted if necessary to maintain a balance of reinforced and unreinforced trials. Except when there were extreme differences, the value of  $X$  was shifted by only one response from one day to the next. Each discrimination condition remained in effect for at least nine sessions, including three or four sessions during which the value of  $X$  was changed only once by not more than one response, and both the median number of responses in the first component and the overall rate of responding in the second component contained no systematic trends. The number

Table 3

Slopes of the linear functions relating first- and second-component responding in the two discrimination conditions. The number of sessions in each condition and the final target value of  $X$  are shown in parentheses. The two right columns show the  $t$ -scores and degrees of freedom for the difference between the slopes.

Bird	DISC1	DISC2	$t$	df
39	3.17 (20, $R \geq 12$ )	-.66 (8, $R \leq 12$ )	4.69**	308
11950	4.56 (20, $R \geq 19$ )	1.23 (13, $R \leq 20$ )	4.93**	260
9432	6.09 (13, $R \geq 5$ )	.48 (17, $R \leq 8$ )	6.66**	290
3620	-1.08 (20, $R \leq 10$ )	.38 (12, $R \geq 25$ )	2.19*	302
11957	1.40 (13, $R \leq 5$ )	.07 (13, $R \geq 8$ )	-1.92	263
11132	-1.18 (9, $R \leq 28$ )	1.17 (14, $R \geq 25$ )	2.61**	249

\* $p < .05$ .

\*\* $p < .01$ .

of sessions for each bird in each condition is shown in Table 3.

### RESULTS

The number of responses in the first component and the rate of responding in the second component were recorded. The slope of the linear function relating first- and second-component responding during the final few sessions of each condition served as an index

of the stimulus control exerted by the number of first-component responses. A positive slope indicated that the rate of responding in the second component was high when there were many responses in the first component and low when there were few responses in the first component; a negative slope indicated the opposite relation. The difference between the slopes across conditions indicated the extent to which the number of first-component responses influenced the rate of responding in the second component.

Figures 4, 5, and 6 show representative data for birds in both replications. Between baseline and discrimination conditions the slopes changed in the predicted directions. That is, the slopes were greater in the  $R \geq X$  condition than in the  $R \leq X$  condition, with intermediate values in the baseline conditions.

The varying length of the second component on reinforced trials presented two difficulties in the analysis of the data. First, the response latency after the food presentation that ended the first component could result in very low rates being recorded if the second component was short. Second, if the component was longer than 15 sec, reinforcement had to occur, and thus the passage of time in the second component as well as the number of responses in the first component might have controlled the rate of responding after 15 sec

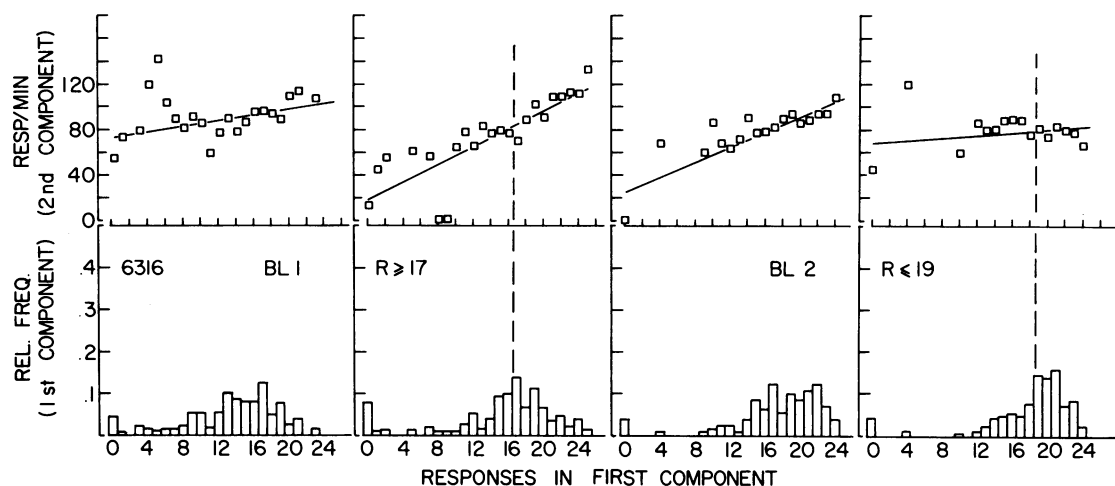


Fig. 4. Data for Bird 6316. The upper panels show the mean rates of responding in the first 15 sec of the second component, plotted as a function of the number of responses in the first component in the various conditions. The line through the points shows the best fitting linear function derived from a trial by trial analysis of first- and second-component responding. The lower panels show the relative frequency distributions of the numbers of responses in the first component. The dashed vertical lines indicate the numbers of responses required ( $R \geq X$ ) or permitted ( $R \leq X$ ) in the first component for reinforcement to occur in the second component.



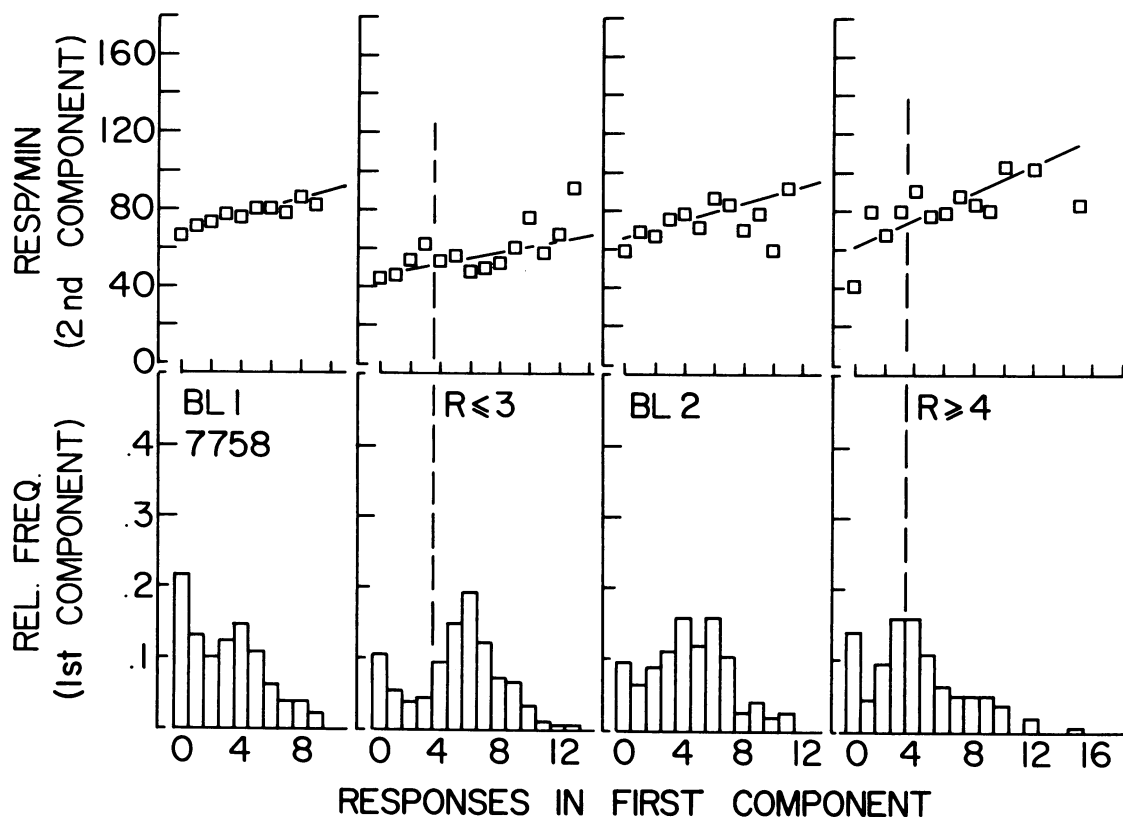


Fig. 5. Data for Bird 7758. The legend is the same as for Figure 4.

had elapsed. In order to sample responding from a constant time period in the second component, trials were excluded from calculations if the second component had been

shorter than 15 sec, and responses after the initial 15 sec were ignored. This restriction excluded up to 25% of the trials from the calculation of the linear functions.

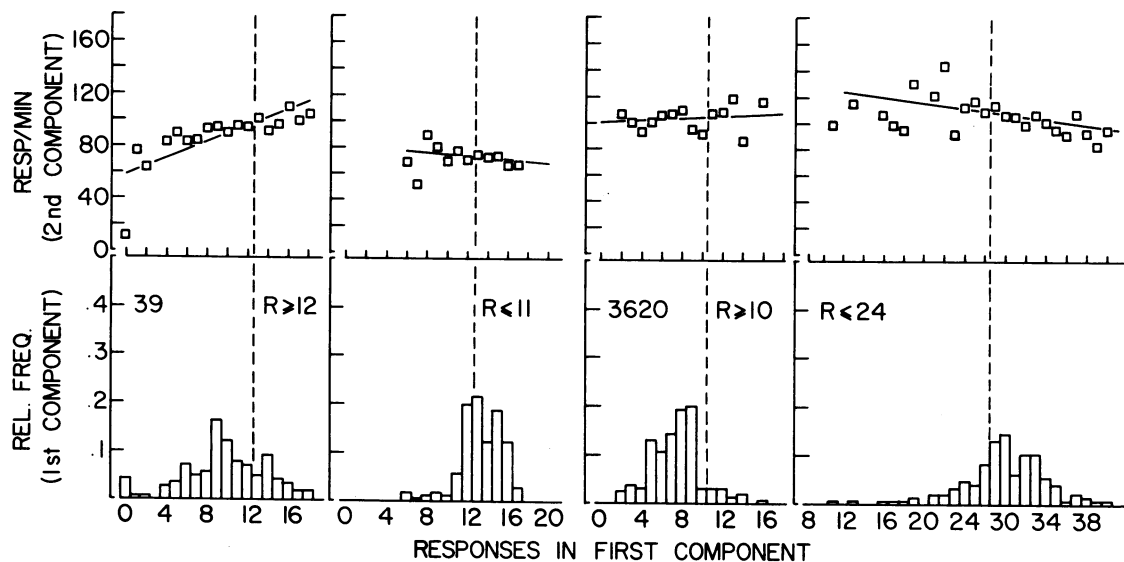


Fig. 6. Data for Birds 39 (left panels) and 3620 (right panels). The legend is the same as for Figure 4.

Table 2 shows, for the first replication, the slopes obtained for the six birds in the two baseline and two discrimination conditions. The baseline slopes were always positive, slopes in the  $R \geq X$  condition were greater than the baseline slopes, and those in the  $R \leq X$  condition were lower than the baseline slopes, though they were not necessarily negative as might have been predicted. For each bird a *t*-test (Mode, 1961) compared the slopes of the two discrimination conditions, and the obtained values and degrees of freedom are shown in the right columns of the table. All six pairs of slopes were reliably different. Within birds, the difference between slopes in the baseline and discrimination conditions was not systematically reliable, but across birds, two paired *t*-tests revealed that the slopes in the second baseline condition, which separated the two discrimination conditions, differed reliably from each of the two discrimination conditions,  $t(5) = 2.134$  for  $R \geq X$ , and  $t(5) = 2.418$  for  $R \leq X$ ,  $p < .05$ , one tailed. A further *t*-test revealed that the absolute magnitude of the deviation of the slopes in the two discrimination conditions from the central baseline condition was not different,  $t(5) = -0.005$ ,  $p > .10$ , indicating that the two discrimination conditions resulted in the same difference in slope, though in opposite directions.

For the second replication, the slopes of the two discrimination conditions and the obtained *t*s and degrees of freedom are shown in Table 3. For Bird 11957, the slopes in the two discrimination conditions did not differ reliably and were opposite from the expected direction, but for the remaining birds the comparisons indicate that the two discrimination conditions engendered different relations

Table 5

Median and interquartile range of the number of responses in the first component in the two discrimination conditions for the birds in the second replication.

Bird	DISC1	DISC2
	$R \geq X$	$R \leq X$
39	11.7(8.8-14.0)	13.0(11.7-14.8)
11950	18.6(17.4-19.9)	18.8(17.5-20.0)
9432	5.5(2.5-7.7)	9.9(7.6-12.3)
	$R \leq X$	$R \geq X$
3620	24.8(23.0-27.8)	8.2(6.2-9.8)
11957	7.5(5.0-9.7)	5.9(4.1-8.4)
11132	26.1(23.8-28.4)	27.5(24.8-29.9)

between first- and second-component responding.

In both replications the median number of responses in the first component did not change systematically across birds between baseline or discrimination conditions, indicating that the number of responses in the first component was not systematically influenced by the differential reinforcement of response number in the second component. Tables 4 and 5 show the median and interquartile range of the number of responses in the first component for each bird and condition.

#### DISCUSSION

The number of responses in an autoshaping trial exerted reliable stimulus control in 11 of 12 birds. The difference between the baseline and discrimination conditions in the first replication indicated that the birds discriminated both the  $R \geq X$  and  $R \leq X$  discrimination conditions from the baseline equally well. When the discrimination was  $R \geq X$  the slope of the regression line relating first- and second-component responding was always positive; when the discrimination was

Table 4

Median and interquartile range of the number of responses in the first component in the baseline and discrimination conditions for the birds in the first replication.

Bird	BL1	DISC1	BL2	DISC2
		$R \geq X$		
			$R \leq X$	
7210	.3(.0-.9)	.4(.0-1.2)	1.1(.3-3.0)	.2(.0-.6)
5679	20.4(17.8-22.4)	14.2(12.6-17.9)	13.9(11.1-16.2)	11.1(9.7-12.9)
6316	14.8(10.5-17.3)	17.7(15.0-19.9)	18.6(15.6-21.2)	18.8(15.9-20.7)
		$R \leq X$		
			$R \geq X$	
6168	9.9(7.0-12.3)	4.5(1.6-6.3)	5.1(2.4-7.7)	4.4(1.7-7.2)
7758	3.0(1.0-4.9)	5.2(2.5-6.9)	4.3(2.4-6.1)	4.4(2.7-7.0)
7778	12.6(11.3-13.8)	12.8(11.3-14.0)	12.1(10.3-13.4)	12.3(11.1-13.3)

$R \leq X$  the slope was negative for six of the 12 birds and somewhat less positive than it had been in the  $R \geq X$  discrimination for five of the 12 birds. The small differences between the slopes across conditions suggested that stimulus control by response number was weak, however.

Stimulus control may have been weak for at least three reasons. First, responses that are apparently elicited and maintained by stimulus-reinforcer relations may be less discriminable than those maintained by explicit response-reinforcer relations. Second, the 2-sec food presentation after the "sample" number of responses had been emitted may have served to degrade the short-term memory of those responses both because it delayed the start of the second component by 2 sec and because the animal engaged in an interpolated eating activity. In rats, retention of response number is degraded by brief time-outs (Johnson & Platt, 1973) and in pigeons, memories for responses may be degraded both by intervening reinforcer presentations (Shimp, 1976) and by intervening stimulus presentations (Maki, Moe, & Bierley, 1977). Third, the range of numbers of responses emitted in the first component was typically small; the interquartile ranges spanned just over three to five responses, sometimes fewer, and usually the most frequent numbers spanned a very narrow range around the value of  $X$  in each discrimination condition. This small range may have made discrimination very difficult.

### GENERAL DISCUSSION

The two experiments showed that the number of responses in an autoshaping trial was manipulable, and that these responses had discriminative stimulus properties. By showing the range over which response requirements may be effective, Experiment 1 extended Wasserman's (1977) report that differential reinforcement could alter response rates and patterns in autoshaping trials.

Although response-reinforcer relations control behavior, it is not necessary to deny concurrent stimulus-reinforcer influences. Woodruff, Conner, Gamzu and Williams (1977) explored parametrically the joint influences of stimulus- and response-reinforcer relations on the keypeck. When stimulus-reinforcer relations were strong, different response-reinforcer relations did not produce differential

responding, and response rates were uniformly high; when stimulus-reinforcer relations were weak, differential response rates to various response-reinforcer relations were readily observed. Furthermore, response rates were greater with strong stimulus-reinforcer relations than with weak ones, regardless of the strength of the response-reinforcer relation. Such data imply that, in general, the stimulus-reinforcer relations are of primary importance in maintaining stimulus-directed behavior, a view that, for omission training at least, is held by Moore (1973), Mackintosh (1974), Hearst and Jenkins (1974), and Schwartz and Gamzu (1977).

The interactive effects of stimulus- and response-reinforcer relations may be more complex than Woodruff et al. (1977) suggested, however. Whereas Woodruff et al. systematically degraded one relation while holding the other constant, in Experiment 1 the response-reinforcer relation was first enhanced and then degraded. The explicit response-reinforcer relations sometimes increased response rates above the rates elicited by the stimulus-reinforcer relation, despite the generally constant stimulus-reinforcer relation. Over the range of requirements in which responding was allowed, it seems that the response-reinforcer relation modulated the eliciting effects of the stimulus-reinforcer relation. Only in omission training, where the stimulus- and response-reinforcer relations were completely opposed, can the key pecks that did occur be attributed to the stimulus-reinforcer relation alone. When the two relations are not opposed, then, it is no simple matter to separate the contribution of each one to the maintenance of the ongoing behavior.

Although response number was modified by differential reinforcement in the first experiment, there was no evidence of such control in the first component of the trials in Experiment 2, even though response number was shown to be discriminable. This was not entirely unexpected. In Reynolds' (1966) study, interresponse times (IRTs) were successfully discriminated in a task that differentially reinforced responding following IRTs greater than 18 sec, but IRTs over 18 sec did not increase in frequency. Likewise, Buchman and Zeiler (1975) found that the number of responses in a first-component fixed interval was not influenced by differential second-

component reinforcement. The results of these experiments suggest that delayed differential reinforcement may be less effective than immediate differential reinforcement. On the other hand, in Experiment 2, the immediate, non-differential food presentation in the first component may have had more influence on first-component responding than the differential reinforcement in the second component. In either case, it appears that the differentiation of some property of responding may depend not only on the successful discrimination of that property, but also upon the retention of the property itself. If, in discrimination tasks, memory involves the formation of an instruction, as Honig (1978) suggests, then the specific memory of the responses may no longer be present when differential reinforcement occurs. The failure of differential reinforcement in these cases, then, suggests that response retention may be more complex and vulnerable to interference than response discrimination in the process of response differentiation.

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